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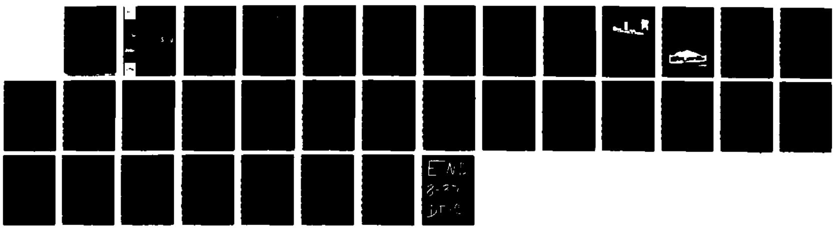

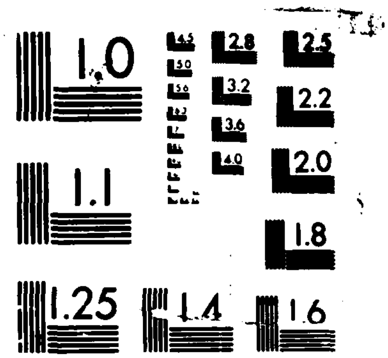
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PAVEMENT EVALUATION CONCEPTS USING NONDESTRUCTIVE STRUCTURAL EVALUATION AND PAVEMENT CONDITION INDEX

by

Jim W. Hall, Jr.

Geotechnical Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

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A logical method for pavement evaluation utilizing both nondestructive procedures for structural analysis and pavement condition distress to identify maintenance needs is presented. Alternatives for maintaining desired serviceability are categorized as routine maintenance, major maintenance, rehabilitation, and reconstruction. The alternatives are selected based on levels of the pavement condition index and results of nondestructive testing structural evaluation. A flowchart outlining the decision process of identifying appropriate alternatives is presented. Specific treatments are selected as a function of the pavement distress type and the severity level of the distress.

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PREFACE

The work reported herein was conducted for the Office, Chief of Engineers (OCE), US Army, under the Facilities Investigation and Studies Program. Technical Monitor at OCE was Mr. R. W. Williams.

The work was performed from October 1984 to September 1986 by Mr. J. W. Hall, Jr., Pavement Systems Division (PSD), Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES). This report was prepared by Mr. Hall under the supervision of Mr. H. H. Ulery, Jr., Chief, PSD, and Dr. W. F. Marcuson III, Chief, GL. Ms. Odell F. Allen, Information Products Division, Information Technology Laboratory, edited this report.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

Contents

Conversion Factors, Non-SI to SI (Metric) Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
inches	2.54	centimetres
kips (force)	4.448222	kilonewtons
pounds (force)	4.448222	newtons
square feet	0.09290304	square metres

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

PAVEMENT EVALUATION CONCEPTS USING NONDESTRUCTIVE STRUCTURAL EVALUATION AND PAVEMENT CONDITION INDEX

Background

1. The Army has many miles of paved roadways and a large number of airfields that must be maintained in satisfactory condition to meet mission requirements. Changes in mission requirements which result in changes in pavement usage create difficult problems for the Directorate of Engineering and Housing (DEH). A pavement management procedure, PAVER (Headquarters, Department of the Army 1982), is being implemented at Army installations to better manage pavement maintenance and plan for optimum use of available funds.

2. Pavement performance and requirements for maintenance are controlled by many factors including traffic loadings, pavement structural capacity, environmental factors, and maintenance programs. Pavement performance is reflected through the condition of the pavement surface at a given time. A measure of this performance is the pavement condition index (PCI) (Headquarters, Department of the Army 1982; Headquarters, Department of the Air Force 1981). The structural capacity of a pavement, which is its ability to withstand imposed traffic loadings, can be measured by nondestructive deflection testing (Hall 1978, Coleman 1984).

3. Pavements may perform at different levels of serviceability. An adequately designed new pavement should begin with a high level of serviceability and should give satisfactory performance for the design life as long as routine maintenance is provided. Exceptions are noted particularly in unusually severe environments or when design and construction specifications are not met. The serviceability level, as measured by the PCI, will generally decrease with age and usage. The structural capacity may also change during the design life because of environmental condition changes, materials deterioration, lack of proper maintenance, and load related fatigue effects. When the PCI drops to an unacceptable level, appropriate maintenance or rehabilitation is required.

4. The PCI and the structural capacity cannot be correlated; therefore, both are necessary items for evaluation of pavement performance. Situations exist where pavements with low PCI may have adequate structural capacity for

loads to be imposed. Other situations include pavements with excellent surface conditions but may not have satisfactory structural capacity for the anticipated traffic loads. The objective of this report is to present a decision process by which the pavement engineer can give proper consideration to both the surface condition and the structural capacity, and recommend appropriate actions to ensure satisfactory performance. Two additional factors which also affect pavement performance are skid resistance and roughness (grade and smoothness); however, they are not addressed in this report because they are beyond the scope of the project.

Nondestructive Structural Evaluation

5. Nondestructive test (NDT) equipment and evaluation procedures have been developed for use on Army roads and airfields. The procedure for airfields was first developed using a correlation method based on the US Army Engineer Waterways Experiment Station (WES) 16-kip* NDT device (Hall 1978). The procedure (Coleman 1984) for roads and streets was similar to the airfield procedure except that a smaller device, the Road Rater Model 2008, was used. Newer procedures (Bush 1980) were developed based on pavement and subgrade stress analyses under specified gear loading over layered elastic media, and employ new load-deflection test devices such as the falling weight deflectometers.

Evaluation of Army airfields

6. According to Hall (1978), TM 5-826-2 (Headquarters, Department of the Army 1980a), and TM 5-826-3 (Headquarters, Department of the Army 1980b), the evaluation procedure presently being used to evaluate the structural capacity of Army airfields uses the WES 16-kip vibrator. This NDT device shown in Figure 1 applies a 16-kip static load to the pavement surface using an 18-in.-diam load plate, and then superimposes a vibratory loading of up to 30 kips peak-to-peak. The vibratory loading is applied at a frequency of 15 Hz. As the vibratory loading is increased from 0 to the maximum, a load-deflection response of the pavement is measured. The vibratory load is monitored by means of three load cells mounted between the actuator and the load

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

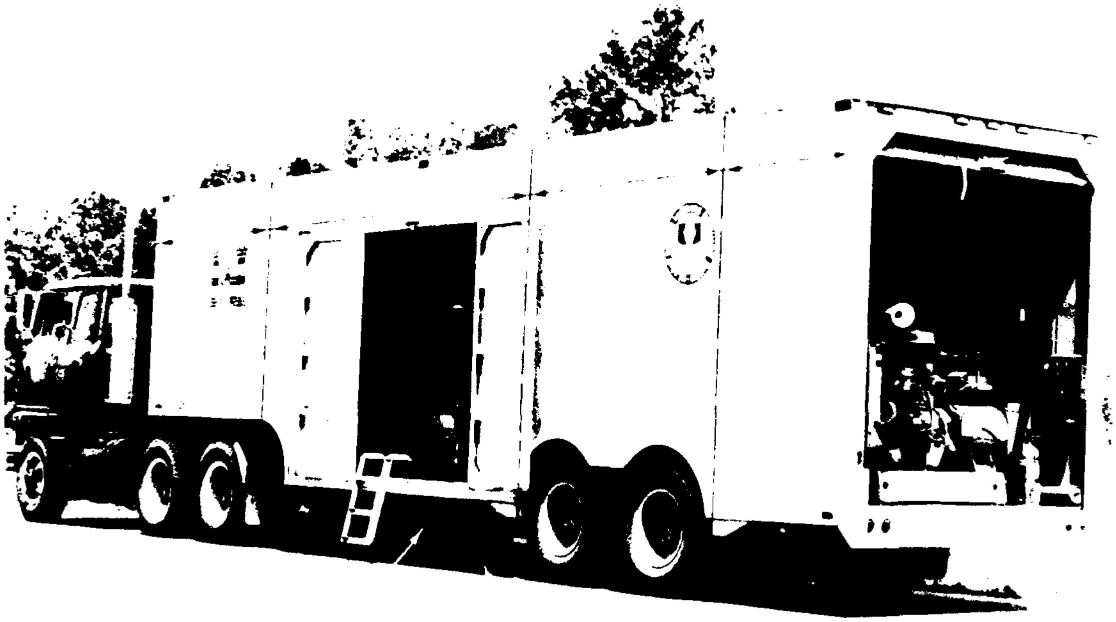

Figure 1. WES 16-kip vibrator

plate, and the pavement deflection response is measured by means of velocity transducers which are electronically integrated to produce deflection. The velocity transducers are mounted on the load plate and at points on the pavement to obtain a deflection basin measurement. Automatic data recording and processing equipment are used to provide the rapid testing capability. From the load-deflection response, a composite modulus of the pavement structure, the dynamic stiffness modulus (DSM), is determined. On runways and primary and high-speed taxiways, DSM tests should be made at least every 250 ft on alternate sides of the center line of the facility along the main gear wheel paths. For secondary taxiway systems or lesser used runways, DSM tests are made about every 500 ft on alternate sides of the center line. For apron areas, DSM tests are conducted in a grid pattern with spacings of 250 and 500 ft. Additional tests are made where wide variations in DSM values are found, depending upon the desired thoroughness of the evaluation.

7. Pavement sections and construction dates must be considered in the actual layout of DSM test sites. Thus, a thorough study of as-built pavement drawings is particularly helpful in designing the testing program. After the DSM tests have been performed and grouped according to pavement type and

construction, a representative DSM value is selected for computation of the allowable loading.

8. The modulus of bituminous materials is highly dependent upon temperature; therefore, an adjustment in the measured DSM must be made if the temperature of the bituminous material at the time of test is not 70° F.

9. The DSM and load-carrying capacity of a pavement system can be significantly changed by the freezing and thawing of the materials, especially when frost penetrates a frost-susceptible layer of material. Correction factors to account for these conditions have not been developed. Therefore, the evaluation should be based on the normal temperature range. If a frost evaluation is desired, the DSM should be determined during the frost-melting period, or a frost evaluation can be made from conventional materials properties and pavement structure data that are available from PAVER (Headquarters, Department of the Army 1982) data files.

10. The DSM value is used with appropriate relationships which have been developed to compute the allowable load capacity for a design aircraft for a specified number of operations, or for the allowable number of operations for a specified aircraft load. Also, for those pavements not structurally adequate, required thicknesses of overlay pavement can be determined.

Figure 2. Road Rater Model 2008

Evaluation of Army roads and streets

11. The nondestructive evaluation procedure for roads and streets is similar to that for airfields except that the Road Rater Model 2008 shown in Figure 2 is used (Coleman 1984, US Army Corps of Engineers 1985).

12. The Road Rater Model 2008 is an electrohydraulic (electronically controlled hydraulic force generator) NDT device that applies a vibratory sinusoidal force to the pavement surface and measures the resulting deflection response. The force is measured with three load cells mounted on an 18-in.-diam steel plate that contacts the pavement surface. Deflections of the pavement surface for the peak-to-peak load are measured with four velocity transducers. These velocities are electronically integrated to produce deflections.

13. The device is housed in a tandem-axle trailer towed by a crew-cab pickup truck. A gasoline engine powers the hydraulic and electrical systems. The force-generating system consists of a 4,000-lb reaction mass, three load cells, a hydraulic actuator, and air springs for centering the reaction mass to provide for equal load distribution. The deflection measurement system consists of velocity transducers located in the center of the loading plate and at 18, 30, and 48 in. from the center of the plate.

14. The digital instrumentation system console contains all the controls and readouts necessary for operation. It is located in the cab of the tow vehicle. After the initial setup, all equipment operations and data collection can be controlled from this console. The data collected are automatically recorded by the printer located in the lower right corner of the console. These data include identification number or test location, force, frequency, and four measured deflections.

15. For roads and streets on military installations, data are collected at 100-ft intervals on opposite sides of the center line. On flexible pavements, the tests are conducted in the outside wheel path of each lane. On rigid pavements, tests are conducted at the center of the slab nearest the 100-ft distance.

16. The simplest and safest method for collecting the data is to test one lane of a street at a time at 200-ft intervals going with the flow of traffic. Electronic distance measuring equipment in the tow vehicle is used to determine the station numbers of the test.

17. In parking areas containing curbs, tests are conducted in the wheel

paths of the traffic lanes. In small parking areas where the 100-ft test spacing is not practical, the tests are spaced to obtain at least three tests per parking area. On large motorpools and open parking areas, tests are conducted in a grid pattern to provide uniform coverage of the area; however, tests are not spaced further than 200 ft apart.

18. The load-deflection measurements are used to calculate the DSM of the pavement section which is then corrected for thermal effects. The DSM for roads and streets using the Road Rater Model 2008 is calculated as a ratio of the difference between the 7.0- and the 5.0-kip load levels to the difference between the plate deflections at these load levels. Stiffer pavements have higher DSM values. Correlations of the corrected DSM to the number of allowable passes of an 18,000-lb single-axle dual-wheel load are then used with existing analytical relationships to determine the number of allowable passes the pavement can support and, if required, the overlay thickness to support anticipated traffic.

19. The NDT evaluation procedures require that the type and thickness of each material in the pavement structure be known. This information can often be obtained from existing facility records such as the as-built drawings, maintenance records, or from the PAVER data base. In areas where information on the pavement structure is incomplete, out-of-date, or nonexistent, it is necessary to determine the pavement structure by coring the pavement. This information should be updated when any rehabilitation (such as placement of an overlay, recycling, or other changes in pavement structure) occurs.

20. Before the structural evaluation of a pavement can be performed, the current daily traffic must be determined and an estimate made of the future traffic. The current daily traffic can be determined from existing records of recent traffic-volume studies or by conducting a traffic-volume study.

21. In the evaluation procedure all traffic is in terms of passes of the 18,000-lb single-axle dual-wheel load or Standard Axle Load (SAL). Traffic data which are not in this form (design index (DI) or vehicles/day for each vehicle classification) are converted to passes of the SAL.

Pavement Surface Condition Rating

22. The procedure (Headquarters, Department of the Army 198[illegible]; Headquarters, Department of the Air Force 1981) for rating of pavement surface

condition on airfields and roads and streets is the PCI, which involves measuring observable surface distresses, applying weighting factors (deduct values) to each distress, and computing an overall surface rating from a scale of 0 to 100. This procedure is an objective rating method based on measuring the quantity and severity of each distress type present in the pavement. Distress types and definitions are slightly different for airfields and roads and streets. For Army roads, there are 19 distress types defined for rigid pavement and 19 for flexible, and for airfield pavements, 15 for rigid and 16 for flexible pavements. These distress types are listed in Table 1. The PCI is a numerical indicator using a scale of 0 to 100 as shown in Figure 3. The PCI

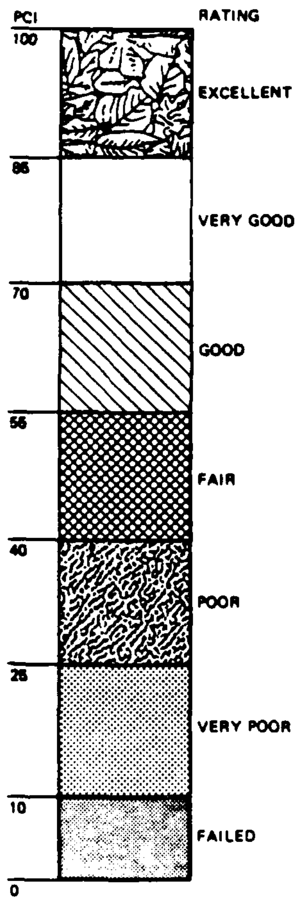

Figure 3. PCI scale

method was developed by correlation of distress measurements on in-service pavements to the subjective rating and collective judgement of a group of pavement engineers.

23. The PCI measures the existing condition of the pavement and is an indicator of its performance to date. The distress types have been categorized as to possible causes as shown in Tables 2 and 3. Maintenance history has an influence on the PCI rating, and the PCI generally increases with completion of maintenance operations. Figure 4 conceptually shows how the PCI changes with time. Shahin and Kohn (1981) have shown relationships between PCI and age for a group of airfield pavements (Figures 5 and 6). Some work has been done in developing performance prediction models using PCI (Shahin et al. 1984), and some work attempted the use of NDT deflection measurements to predict PCI (O'Brien, Kohn, and Shahin 1983). As yet, the performance models have not been used in pavement evaluation, but they do appear to hold promise. Further development of prediction models might allow more precise planning of maintenance, rehabilitation, and reconstruction alternatives. An accurate prediction of future PCI levels combined with probable service life of available alternatives could provide large potential for cost savings.

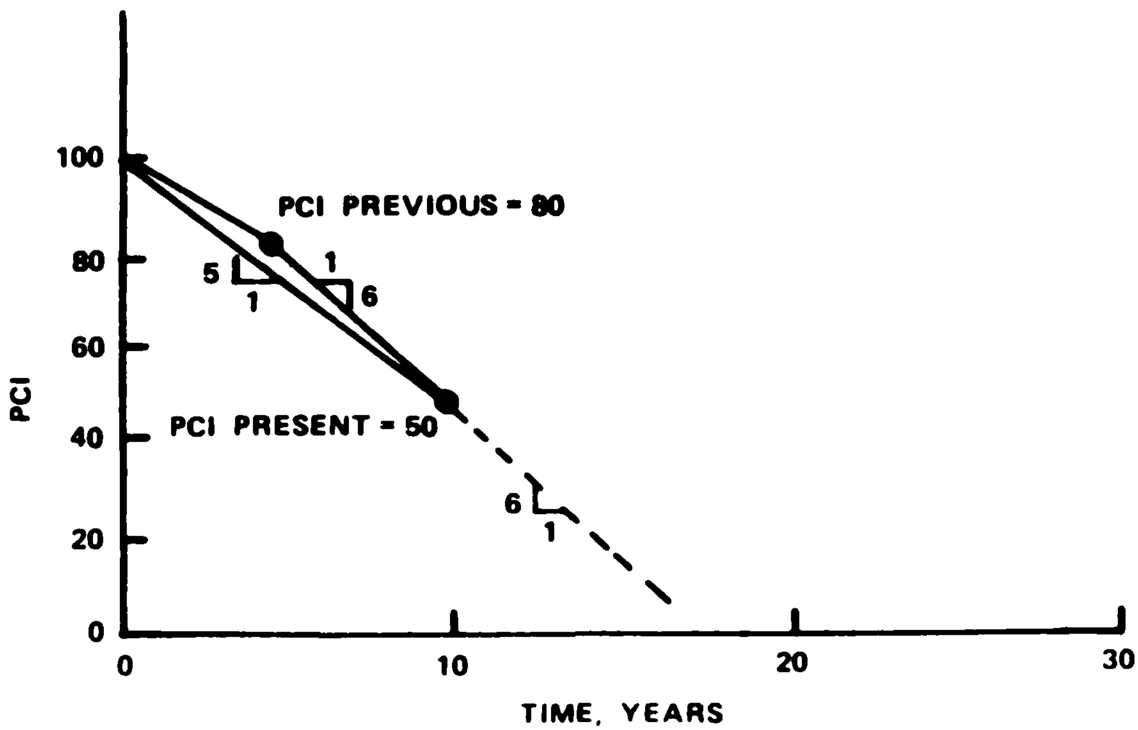

Figure 4. Change in PCI with pavement age

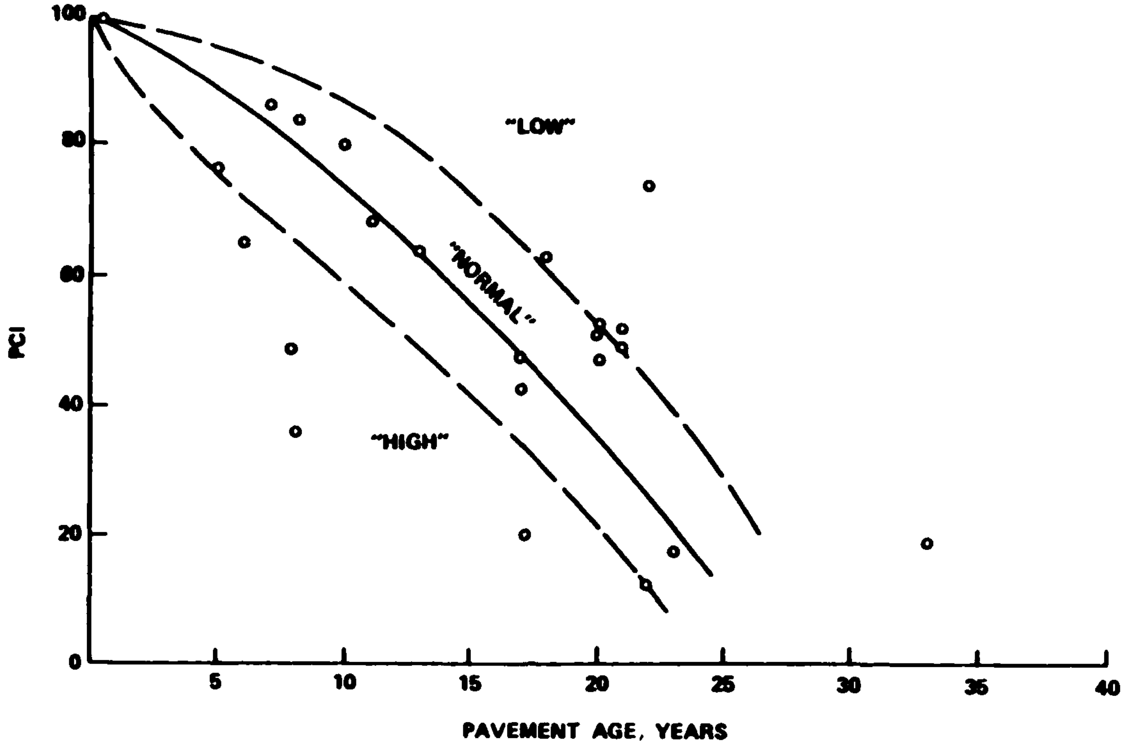

Figure 5. PCI of flexible pavement features versus time since construction (or since last overlay)

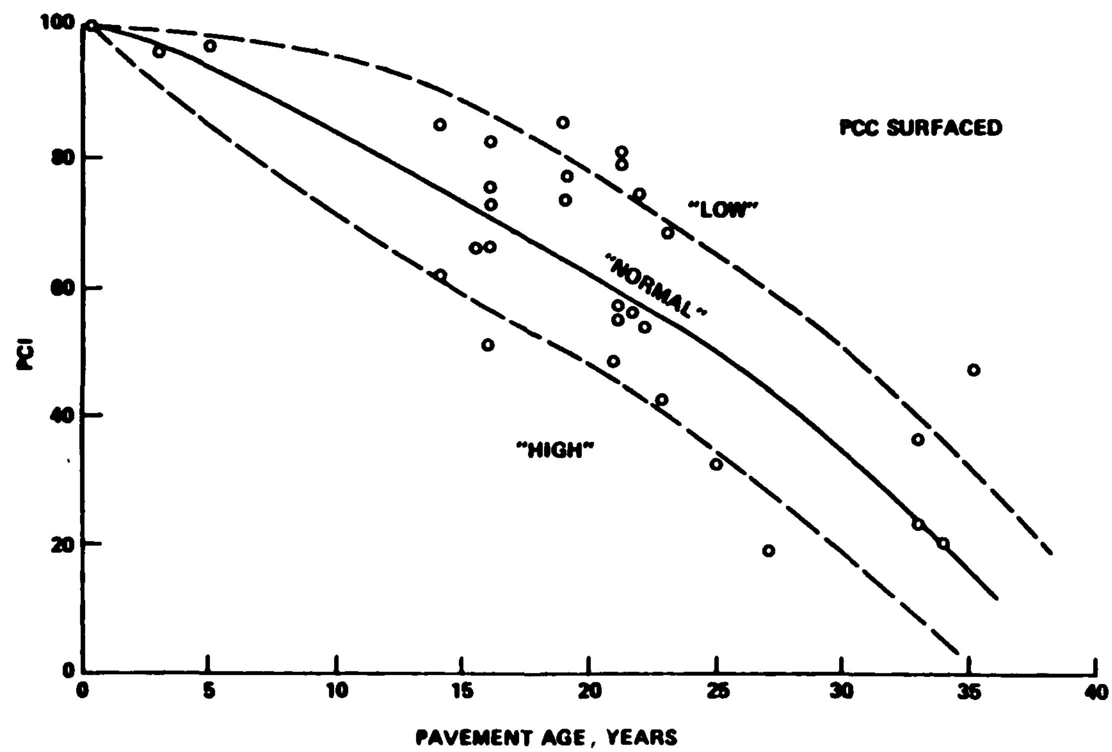

Figure 6. PCI of jointed rigid pavement features versus time (since construction)

Maintenance, Rehabilitation, and Reconstruction Requirements

24. Pavement distresses are the result of a complex combination of factors which may include environment (temperature, rainfall, freeze-thaw, and wind), materials of construction, improper construction practices, load history (magnitude and frequency of loads), age, inadequate pavement design, and lack of adequate maintenance. In order for a pavement to provide a minimum acceptable level of serviceability, certain maintenance must be accomplished. Pavement deterioration is inevitable and must be considered in the pavement management plan. The degree of maintenance will be dictated by the type and rate of deterioration.

25. The purpose of a maintenance program is to prevent strength reductions due to moisture increases in the pavement foundation, retard the development of cracks and other types of degradation of the pavement surface, prevent roughness and loss of ride quality, and keep the pavement in an overall condition that will provide the desired level of serviceability. Properly designed and constructed pavements will have the structural capacity to support the design loads. However, moisture can enter the pavement foundation through improperly sealed cracks and joints and reduce the structural capacity to the point where structural deterioration will begin. At the same time, environmental deterioration begins with oxidation of asphalt surfaces to cause raveling and cracking, and concrete surfaces can result in scaling, spalling, and cracking.

Alternatives Defined

26. The alternatives for maintaining the desired level of pavement serviceability are defined in four categories: (1) routine maintenance, (2) major maintenance, (3) rehabilitation, and (4) reconstruction.

Routine maintenance

27. Routine maintenance is defined as the regularly scheduled maintenance operations such as sealing minor cracks and joints, repairing potholes, small patching, and minor spalls, applying pavement rejuvenators, keeping drainage facilities open, and other normal day-to-day operations. Routine maintenance is considered as preventative maintenance. Routine maintenance is

needed when the PCI is between 70 and 95; however, this type of maintenance is a continuous program, and the cost for routine maintenance should be included in each year's budget.

Major maintenance

28. Periodic maintenance is required to correct distresses that are not included in routine maintenance. This is termed major maintenance and is appropriate at PCI levels between 40 and 70. Frequency of occurrence of these distresses is not predictable because of the complexity of the nature of factors involved. Some major maintenance to pavements may be required on an annual basis, and some pavements may perform for several years before needing such maintenance. Items of major maintenance include sealing major cracks and joints, providing new surface texture and crack sealing with surface treatments and slurry seals, repairing failed areas with large patches, thin overlays, and porous friction courses, correcting surface roughness by surface milling (cold planing), and repairing drainage facilities.

Rehabilitation

29. This alternative is selected when the PCI falls between 25 and 40 and is required because of significant distress conditions. Rehabilitation is required when a pavement has deteriorated to a condition which makes it no longer economically feasible or operationally acceptable to maintain serviceability with major maintenance. Rehabilitation is usually performed on pavements with badly deteriorated surfaces (Asphalt Concrete (AC) or Portland Cement Concrete (PCC)) having satisfactory foundation layers. Occasionally rehabilitation may also involve correcting subsurface or surface drainage. Rehabilitation operations may also be necessary to correct very rough pavement surfaces. Rehabilitation includes such operations as replacing slab, repairing or installing drainage systems, cracking and seating PCC with overlay, applying overlays with either AC or PCC, and utilizing fabric or asphalt-rubber interlayers with overlays. A structural overlay may be included as part of rehabilitation if the NDT evaluation identifies the need for structural upgrading.

Reconstruction

30. When a pavement structure has deteriorated beyond salvation by rehabilitation, then reconstruction is required. Pavements with poor quality foundation materials (base, subbase, subgrade) or extremely poor drainage resulting in weak structural support are candidates for reconstruction.

Reconstruction may involve recycling techniques which include the complete removal of the existing pavement structure, replacing with new materials, or satisfactorily improving existing materials. Pavements with PCI of 25 or below are recommended for reconstruction. Pavements with very low structural ratings requiring excessively thick overlays for upgrading may be corrected more economically by reconstruction. Reconstruction may include structural upgrading if the NDT evaluation identifies a structural deficiency in the existing pavement system.

Selection of Alternatives

31. The decision as to the most appropriate treatment consisting of routine maintenance, major maintenance, rehabilitation, or reconstruction can be made from the pavement evaluation results. A decision process is presented in Figure 7. In this process, both the PCI condition rating and the NDT

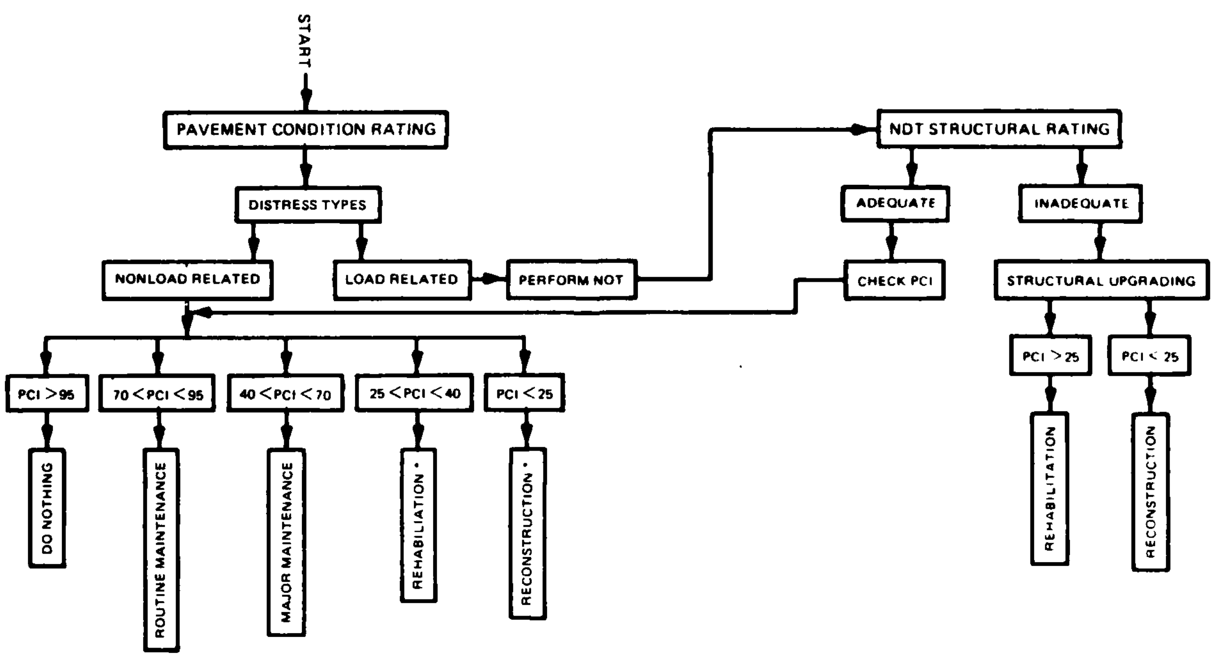

Figure 7. Flowchart for pavement evaluations

structural rating are used. Figure 7 is a flowchart that allows the determination of the most appropriate alternative to maintenance, rehabilitation, or reconstruction.

32. The PCI should be the first measurement made for evaluation of a pavement, and the results should be input into Figure 7. A PCI evaluation should be conducted every 2 to 3 years. If all of the distresses measured are nonload related and if there is no planned change in usage of the pavement (neither increased loads nor frequency), and the same traffic has been consistent for 2 years or more, then there may not be a need for the NDT evaluation, particularly if such an evaluation was conducted within the last 5 years. If an NDT evaluation has not been made within 5 years, an assessment of the structural capacity by NDT should be made, even if the PCI does not indicate load-related distresses. If the PCI identifies significant load-related distresses, the requirement for an NDT structural evaluation is triggered.

33. Maintenance alternatives as a function of distress types are given in Tables 4 through 7. Alternatives for rehabilitation and reconstruction, which may be a requirement of either surface condition or structural evaluation (see Figure 7) are given in Tables 8 through 11.

34. When the PCI shows only nonload related distresses, only the numerical value of the PCI is necessary to select the appropriate alternative (Figure 7). Tables 4, 5, 6, and 7 are then entered with the alternative type along with the specific distress types and severity levels to select the maintenance operation or operations that should be used. When more than one type of distress exists, the maintenance operation that will correct all the distresses is selected.

35. If load-related distresses are identified from the condition rating, an NDT structural rating is performed. An NDT evaluation may also be called for because of changes in pavement usage or unknown structural conditions. If the structural capacity is found inadequate, structural upgrading is required. This normally consists of applying a structural overlay, but depending on existing surface conditions, it may involve other additional treatments to improve the structural capacity to the design requirement. When the overlay thickness requirement is excessive, reconstruction may be the most economical alternative. When extensive cracking is indicated by the PCI, additional treatments such as geotextiles or asphalt-rubber interlayers may be beneficial to retard reflection cracking in the overlay. Recycling of AC pavements is used to reduce cracking in overlays. The specific alternative for structural upgrading is found using results from Figure 7 and the information from Tables 8, 9, 10 and 11. When the PCI is greater than 25, the

structural upgrading is defined as rehabilitation. For a PCI less than 25, reconstruction is normally the requirement.

36. Figure 7 along with Tables 4 through 11 provide guidance in selection of routine and major maintenance, rehabilitation, reconstruction, and structural upgrading for flexible and rigid pavements. However, it must be remembered that this procedure is not all inclusive, and factors such as surface roughness, skid resistance, and other factors must also be considered. Engineering judgement must be applied when utilizing this procedure, and local experience and performance history should be recognized.

37. The procedure presented herein is not based on any new data or information, but simply combines existing pavement evaluation information in a logical form. It provides a format for the rational use of combined pavement condition rating and pavement structural capacity. This procedure is only intended as a guide; each pavement evaluation project requires engineering analysis and in-depth study. This procedure should be made part of the PAVER program which already contains the framework and much of the information to perform the analysis.

38. Additional developmental research needs to be conducted to determine if the PCI can be used to measure the amount of the structural life that has been used. Presently, the NDT structural rating does not account for the pavement life used by past traffic. Along these same lines, studies need to be conducted to define the relationship of laboratory fatigue testing to field performance/damage factors. Laboratory testing may provide the link to accurate predictions of pavement fatigue deterioration.

Conclusions and Recommendations

39. This report provides a procedure to improve the use of pavement evaluation results in terms of surface condition evaluation and nondestructive structural evaluation. Specific conclusions and recommendations are as follows:

- a. The PCI evaluation should be performed periodically (2- to 3-year intervals) to determine rate of deterioration of pavement surfaces.
- b. PCI results should be used to determine when a nondestructive structural evaluation is necessary based on structural

deterioration. PCI distresses related to structural causes identify the need for the structural evaluation.

c. Nondestructive structural evaluations should be performed whenever indicated by PCI evaluation results, whenever the traffic loading levels change significantly, or at 5-year intervals.

d. Optimum alternatives for pavement maintenance, rehabilitation, reconstruction, or structural upgrading can only be determined from a total evaluation based on both PCI and NDT results.

e. Additional research is needed to further develop the pavement evaluation method to: (1) use PCI to measure the amount of pavement life used by past traffic, (2) relate laboratory fatigue testing to field performance, (3) predict anticipated life expectancy of various alternatives, (4) provide optimization of cost/benefit of alternatives, and (5) include criteria for skid resistance and roughness into the evaluation for both airfields and roads and streets.

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Table 1

Pavement Surface Distress Types

Flexible	Rigid
Airfields	
1. Alligator cracking	1. Blowup
2. Bleeding	2. Corner break
3. Block cracking	3. Longitudinal, transverse, or diagonal crack
4. Corrugation	4. "D" cracking
5. Depression	5. Joint seal damage
6. Jet blast	6. Patching, <5 ft^2
7. Reflection cracking	7. Patching/utility cut
8. Longitudinal and transverse cracking	8. Popouts
9. Oil spillage	9. Pumping
10. Patching	10. Scaling/map cracking/crazing
11. Polished aggregate	11. Faulting
12. Raveling/weathering	12. Shattered slab
13. Rutting	13. Shrinkage crack
14. Shoving	14. Spalling (joint)
15. Slippage cracking	15. Spalling (corner)
16. Swell	
Roads and Streets	
1. Alligator cracking	1. Blow-up buckling/shattering
2. Bleeding	2. Corner break
3. Block cracking	3. Divided slab
4. Bumps and sags	4. Durability (D) cracking
4. Corrugation	5. Faulting
6. Depression	6. Joint seal damage
7. Edge cracking	7. Lane/shoulder drop off
8. Reflection cracking	8. Longitudinal, transverse, or diagonal crack
9. Lane/shoulder drop off	9. Patching (large) and eight utility cuts
10. Longitudinal and transverse cracking	10. Patching (small)
11. Patching and utility cut patching	11. Polished aggregate
12. Polished aggregate	12. Popouts
13. Potholes	13. Pumping
14. Railroad crossing	14. Punchout
15. Rutting	15. Railroad crossing
16. Shoving	16. Scaling/map cracking/crazing
17. Slippage cracking	17. Shrinkage cracks
18. Swell	18. Spalling (corner)
19. Raveling/weathering	19. Spalling (joint)

Table 2

Airfield Pavement Distress Types by Possible Causes

Load	Climate/Durability/Materials	Moisture/Drainage	Other Factors
	Asphalt Distress Types		
Alligator cracking	Bleeding	Alligator cracking	Corrugation
Corrugation	Block cracking	Depression	Bleeding
Depression	Joint reflection cracking	Swell	Jet blast
Polished aggregate	Longitudinal and transverse cracking	Rutting	Oil spillage
Rutting	Patching of climate/durability-swell caused distress	Longitudinal/transverse cracking	
Slippage cracking	Swell		
Shoving	Raveling/weathering		
Patching	Shoving		
	Polished aggregate		
	Concrete Distress Types		
Corner break	Blowup	Corner break	Faulting
Shattered slab	D cracking	Shattered slab	Utility cut
Patching	Joint seal damage	Patching	
Spalling (joint)	Longitudinal/transverse/diagonal cracking	Pumping	
Longitudinal/transverse/diagonal cracking	Patching of climate/durability-associated distress	Faulting	
Pumping	Popouts	Longitudinal/transverse/diagonal cracking	
Faulting	Pumping		
	Scaling/map cracking/crazing		
	Shrinkage cracks		
	Spalling (joint)		
	Spalling (corner)		

Table 3

Road and Street Distress Types by Possible Causes

Load	Climate/Durability/Materials	Moisture/Drainage	Other Factors
	Asphalt Distress Types		
Alligator cracking	Bleeding	Alligator cracking	Corrugation
Corrugation	Block cracking	Depression	Bumps and sags
Depression	Joint reflection cracking	Potholes	Lane/shoulder drop off
Edge cracking	Longitudinal and transverse cracking	Swell	Railroad crossing
Patching	Patching of climate/durability-swell caused distress	Patching	
Polished aggregate	Potholes	Longitudinal/transverse cracking	
Potholes	Swell		
Rutting	Raveling/weathering		
Slippage cracking	Polished aggregate		
Shoving			
	Concrete Distress Types		
Corner break	Blowup	Corner break	Faulting
Divided slab	D cracking	Divided slab	Lane/shoulder drop off
Linear cracking	Joint seal damage	Patching of moisture-caused distress	Railroad crossing
Patching	Linear cracking	Pumping	
Polished aggregate	Patching	Faulting	
Punchout	Popouts	Longitudinal/transverse/diagonal cracking	
Spalling (joint)	Pumping		
Pumping	Scaling/map cracking/crazing		
Faulting	Shrinkage cracks		
	Spalling (joint)		
	Spalling (corner)		
	Polished aggregate		

Table 4

Maintenance Alternatives for Airfield Pavements, Flexible

	Routine Maintenance				Major Maintenance								
Distress Type	Seal Minor Cracks	Repair Potholes	Small Patching	Apply Rejuvenators*	Seal Major Cracks	Large Patching	Surface Treatment**	Slurry Seal†	Thin AC Overlays††	Surface Milling	Grooving	Porous Friction Course	Repair Drainage Facilities‡
Alligator cracking	L	M,H	M			M,H	L	L					L,M,H
Bleeding										L,M			
Block cracking	L,M			L	M,H		L,M	L					
Corrugation			L,M			L,M,H			M,H	L,M			
Depression			L,M,H			M,H			M,H				L,M,H
Jet blast				A		A			A				
Reflection cracking	L,M				M,H		L,M	L					
Longitudinal and transverse cracking	L,M				M,H		L,M	L					
Oil spillage			A			A			A	A			
Patching	L,M		M		M	M,H							
Polished aggregate							A	A	A	A	A	A	
Raveling/weathering		M,H		L,M		M	L,M	L	M,H	M			
Rutting			L,M			L,M,H							L,M,H
Shoving			L			L,M				L,M			
Slippage cracking	L		L,M		L,M	M,H							
Swell			L,M			M,H				L,M			L,M,H

Note: L = low severity level; M = medium severity level; H = high severity level; A = no severity levels for this distress.
* Not to be used on high speed areas due to increased skid potential.
** Not to be used on high-type airfields due to FOD potential.
† Not to be used on heavy traffic areas.
†† Patch distressed areas prior to overlay.
‡ Drainage facilities to be repaired as needed.

Table 5

Maintenance Alternatives for Airfield Pavements, Rigid

Distress Type	Routine Maintenance				Major Maintenance							
	Seal Minor Cracks	Joint Seal	Partial Patch	Epoxy Repairs	Seal Major Cracks	Full-Depth Patch	Under Sealing	Slab Grinding	Surface Milling	AC Overlay	PCC Overlay	Repair Drainage Facilities*
Blowup			L,M			M,H						
Corner break	L			M,H	M,H	M,H						
Longitudinal/transverse/ diagonal cracking	L,M				M,H					H	H	L,M,H
D cracking	L		M,H		M,H	H						
Joint seal damage		M,H										
Patching (small) <5 ft^2	L,M		M	L,M	M,H	M,H						
Patching/utility cut	L,M		M	L,M	M,H	M,H						
Popouts**				A						A	A	
Pumping	A	A			A		A					A
Scaling/map cracking			M,H					M,H		M,H	M,H	
Fault/settlement		L,M					M,H	L,M	M,H			L,M,H
Shattered slab	L				L,M					M,H	M,H	L,M,H
Shrinkage crack†												
Spalling (joints)		L	L,M	L,M,H	M,H	M,H						
Spalling (corner)			L,M	L,M	M,H	M,H						

Note: L = low severity level; M = medium severity level; H = high severity level; A = no severity levels for this distress.
* Drainage facilities to be repaired as needed.
** Popouts normally do not require maintenance.
† Shrinkage cracks normally do not require maintenance.

Table 6

Maintenance Alternatives for Roads and Streets, Flexible

Distress Type	Routine Maintenance				Major Maintenance							
	Seal Minor Cracks	Repair Potholes	Small Patching	Apply Rejuvenators*	Seal Major Cracks	Large Patching	Surface Treatment	Slurry Seal**	Thin AC Overlays†	Surface Milling	Grooving	Repair Drainage Facilities††
Alligator cracking	L	M,H	M			M,H	L	L				L,M,H
Bleeding										L,M		
Block cracking	L,M			L	M,H		L,M	L				
Bumps & sags			L,M			M,H			M,H	L,M		
Corrugation			L,M			L,M,H				L,M		
Depression			L,M,H			M,H			M,H			L,M,H
Edge cracking	L,M		M,H		M,H	M,H						L.M.H
Joint reflection cracking	L,M				M,H		L,M	L				
Lane/shoulder drop off	L,M				M,H							
Longitudinal and transverse cracking	L,M				M,H		L,M	L				L,M,H
Patching and utility cut	L,M				M,H							
Polished aggregate							A	A	A	A	A	
Potholes		L,M,H	M,H			M,H						L,M,H
Railroad crossing			L,M			M,H						L,M,H
Rutting			L,M			L,M,H						L,M,H
Shoving			L			L,M				L,M		
Slippage cracking	L		L,M		L,M	M,H						
Swell			L,M		L,M	M,H				L,M		L,M,H
Raveling/weathering		M,H		L,M		M	L,M	L	M,H	M		

Note: L = low severity level; M = medium severity level; H = high severity level; A = no severity levels for this distress.
* Not to be used on high speed areas due to increase in skid potential.
** Not to be used on heavy traffic areas.
† Patch distressed areas prior to overlay.
†† Drainage facilities to be repaired as needed.

Table 7

Maintenance Alternatives for Roads and Streets, Rigid

	Routine Maintenance				Major Maintenance								
Distress Type	Seal Minor Cracks	Joint Seal	Partial Patch	Epoxy Repairs	Seal Major Cracks	Full-Depth Patch	Under Sealing	Slab Grinding	Surface Milling	Grooving	AC Overlay	PCC Overlay	Repair Drainage Facilities*
Blowup			L,M			M,H							
Corner break	L			M,H	M,H	M,H							
Divided (shattered) slab	L				L,M						M,H	M,H	L,M,H
D cracking	L		M,H		M,H	H							
Faulting (settlement)							M,H	L,M	M,H				L,M,H
Joint seal damage		M,H											
Lane/shoulder drop off	L,M				M,H								
Linear (longitudinal/transverse/diagonal) cracking	L,M				M,H								L,M,H
Large patching (utility cut)	L,M		M	L,M	M,H	M,H					H	H	
Small patching	L,M		M	L,M	M,H	M,H							
Polished aggregate									A	A			
Popouts**				A							A	A	
Pumping	A	A			A		A						A
Punchout			L			M,H							L,M,H
Railroad crossing			L,M			M,H							
Scaling/map cracking/crazing			M,H				M,H				M,H	M,H	
Shrinkage cracks†													
Spalling (corner)			L,M	L,M,H	M,H	M,H							
Spalling (joint)		L	L,M	L,M,H	M,H	M,H							

Note: L = low severity level; M = medium severity level; H = high severity level; A = no severity levels for this distress.

* Repair drainage facilities as needed.

** Popouts normally do not require maintenance.

† Shrinkage cracks normally do not require maintenance.

Table 8

Rehabilitation and Reconstruction Alternatives for Airfield Pavements, Flexible

	Rehabilitation				Reconstruction			
Distress Type	Surface Recycling	AC Structural Overlay*	Install/Repair Subsurface Drainage Facilities	PCC Structural Overlay	Remove Existing Surface and Reconstruct	Hot Recycle	Cold Recycle	AC Structural Overlay
Alligator cracking		M,H	L,M,H	M,H	H			H
Bleeding	M,H				H	M,H	M,H	
Block cracking	M	M,H				M,H	M,H	
Corrugation					M,H			
Depression			L,M,H		H			
Jet blast								
Reflection cracking		M,H				H		
Longitudinal and transverse crack		M,H				H		
Oil spillage	A				A	A		
Patching		M,H			H	H		M,H
Polished aggregate	A							
Raveling	M,H			H	H	M,H		
Rutting		M,H	L,M,H	H	H	M,H		M,H
Shoving					M,H	M,H		L,M
Slippage cracking		M,H			M,H	M,H		L,M
Swell			L,M,H		H			

Note: M = medium severity level; H = high severity level; L = low severity level; A = no severity levels for this distress.
* Patch distressed areas prior to overlay.

Table 9

Rehabilitation and Reconstruction Alternatives for Airfield Pavements, Rigid

	Rehabilitation						Reconstruction	
Distress Type	Slab Replacement	AC Structural Overlay	PCC Structural Overlay	Crack & Seat with AC Structural Overlay	AC Structural Overlay w/Geotextile	Repair/Install Surface/Subsurface Drainage System	PCC Recycling	Remove Existing PCC & Reconstruct
Blowup	H							
Corner break	H							
Longitudinal/transverse/ diagonal cracking	H	H	H	M,H	H	L,M,H	H	H
D cracking	H						H	H
Joint seal damage								
Patching (small) <5 ft^2	H							
Patching/utility cut	H							H
Popouts*								
Pumping						A		
Scaling/map cracking/crazing		M,H	M,H					
Fault/settlement						L,M,H		
Shattered slab	M,H				H	L,M,H	H	H
Shrinkage crack**								
Spalling (joints)								
Spalling (corner)								

Note: H = high severity level; M = medium severity level; L = low severity level; A = no severity levels for this distress.
* Popouts normally do not require maintenance.
** Shrinkage cracks normally do not require maintenance.

Table 10

Rehabilitation and Reconstruction Alternatives for Roads and Streets, Flexible

	Rehabilitation				Reconstruction				
Distress Type	Surface Recycling	Repair/Resurface Shoulders	AC Structural Overlay*	PCC Overlay	Install Surface/Subsurface Drainage Facilities	Cold Recycle	Hot Recycle	AC Structural Overlay	Remove Existing Surface and Reconstruct
Alligator cracking			M,H	M,H	L,M,H			H	H
Bleeding	M,H					M,H	M,H		H
Block cracking	M		M,H			M,H	M,H		H
Bumps and sags						H	H		H
Corrugation									M,H
Depression					L,M,H				H
Edge cracking		M,H							
Joint reflection cracking			M,H				H		
Lane/shoulder drop off		L,M,H							H
Longitudinal and transverse cracking			M,H		L,M,H				
Patching and utility cut			H				M,H	M,H	
Polished aggregate	A								
Potholes						H	H		H
Railroad crossing									
Rutting			M,H	H	L,M,H		M,H	M,H	
Shoving							M,H	L,M	M,H
Slippage cracking			M,H				M,H	L,M	M,H
Swell					L,M,H				H
Weathering and raveling	M,H			H			M,H		H

Note: M = medium severity level; H = high severity level; L = low severity level; A = no severity levels for this distress.
* Patch distressed areas prior to overlay.

Table 11

Rehabilitation and Reconstruction Alternatives for Roads and Streets, Rigid

	Rehabilitation							Reconstruction	
Distress Type	Slab Replacement	AC Structural Overlay	PCC Structural Overlay	Crack & Seat with AC Structural Overlay	AC Structural Overlay with Geotextile	Repair/Install Surface/Subsurface Drainage System	Repair/Resurface Shoulders	PCC Recycling	Remove Existing PCC & Reconstruct
Blowup	H								
Corner break	H								
Divided (shattered) slab	M,H								
D cracking	H			H	H			H	H
Faulting (settlement)						L,M,H			
Joint seal damage									
Lane/shoulder drop off							M,H		H
Longitudinal/Transverse/ Diagonal cracking		H	H	M,H	H	L,M,H		H	H
Large patching (utility cut)	H								H
Small patching	H								
Polished aggregate	H								
Popouts*									
Pumping						A			
Punchout	M,H					L,M,H			H
Railroad crossing									
Scaling/map cracking/crazing		M,H	M,H	M,H					
Shrinkage cracks**									
Spalling (corner)									
Spalling (joint)									

Note: H = high severity level; M = medium severity level; L = low severity level; A = no severity levels for this distress.
* Popouts normally do not require maintenance.
** Shrinkage cracks normally do not require maintenance.

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